Shear bond strength of two ceramic repair system to lithium disilicate: An in-vitro comparison

Valentine Rosadi Sinaga[1*], Setyawan Bonifacius[1], Taufik Sumarsongko[1]

[1]Department of Prosthodontics, Faculty of Dentistry Universitas Padjajaran, Indonesia

ABSTRACT

Introduction: The improvement of ceramic has increased due to the high demand for aesthetic restoration. Ceramic in nature is a brittle material that highly susceptible to be cracked, which leads to chipping and fracture of the restoration. Composite resin is frequently used as a replacement for ceramic repair as a simple and fast solution. The success relies on the bond strength between ceramic and composite. The purpose of this study was to compare the difference in shear bond strength between ceramic repair systems using grinding and universal primers with those using etching hydrofluoric acid and silane on lithium disilicate. **Methods:** This study was an experimental laboratory, ten blocks (10x10x2mm) of lithium disilicate was divided into two groups of two ceramic repair system. The first group included: grinding and treated with ceramic primer, and the second group: acid-etched with hydrofluoric acid and treated with silane. Composite resin from each ceramic repair system was applied in both groups. Each specimen was subjected under a load of 5.6 kN with the crosshead speed of 0,5 mm/minutes until fracture using a universal testing machine (LLOYD Instruments LRX Plus). **Results:** The shear bond strength achieved in group two (acid etching and silane) was 13.51 MPa, which was higher than the group one (grinding and ceramic primer) (6.17 MPa). The t-test one-tailed analysis yielded p-value of 0.001. The different was significant (p-value < 0.05). **Conclusion:** In this study, it is concluded that when treated with acid etching hydrofluoric acid and silane, lithium disilicate yielded higher bond strength with resin composite compared to grinding and ceramic primer.

Keywords: ceramics; composite resins; dental bonding; dental porcelain; dental prosthesis repair system.

INTRODUCTION

Comprehensive prosthodontics treatments restore the oral functional system along with the optimum aesthetic value. For decades, metal-ceramic restoration has been widely used as a gold standard[1,2], for either single restoration or bridges, but nowadays, an ceramic restoration without metal layer has been considered as restoration with more optimum aesthetic value therefore increasing its demand.[3,4,5,6,7] The aesthetic limitation of metal ceramic restorations has led

p-ISSN: 1979-0201; e-ISSN: 2549-6212; Available from: http://jurnal.unpad.ac.id/pjd/article/view/18950
DOI: 10.24198/pjd.vol33no2.18950
Submission: Oct 11, 2018; Accepted: Jul 30, 2021; Published online: Jul 31, 2021

**Corresponding author: Valentine Rosadi Sinaga, Department of Prosthodontics, Faculty of Dentistry Universitas Padjdjaran, Indonesia. Jalan Sekeloa Selatan I, Bandung, West Java, Indonesia, 40132. Phone: +62 812-1404-4486; e-mail: valentinerosadi@gmail.com*

to the development of all ceramics restorations to be used on many forms of restoration. Many ceramic restoration systems available on the market offer a very high aesthetic value because basically ceramic transmits light like the natural tooth structure.[3,8] Major developments in the last decade show that all ceramic restorations have lower success rates than metal-ceramic restorations because of their material properties, which is low flexural strength, high modulus of elasticity, brittleness and crack propagation.[5,9]

Ceramics have many advantages, which are more stable color, radiopaque properties, coefficient of thermal expansion that resembles dentin, good compression, abrasion resistance, and high aesthetic value.[3,4,10] Naturally, ceramics are inherently fragile and tend to fracture easily in repetitive function. Chewing pressure is usually compressive, but tensile stress on bridges and crowns cannot be avoided. Cracks tend to follow paths where the tensile pressure are greatest.[3,9]

Lithium disilicate has been very popular in recent years because of this material's adhesive properties and its preservation of tooth structure. Lithium disilicate has a high survival rate based on short and long term survival evidence for each single crown restoration and three unit fixed dental prostheses (FDP). The manufacturer (Ivoclar Vivadent) start using lithium disilicate as a framework where the veneering material was fluor-apatite based ceramic.[5]

Dental materials and interfaces between core and ceramic veneering will be affected by various conditions in the oral cavity: pressures from the masticatory force and also the changes in temperature, saliva, and mouth acidity.[9] Cracks that continue to fracture in the anterior area will cause aesthetic problems, and if it occurs in the posterior area, it can also interfere with the function of mastication. Ceramic fractures can occur from several factors, namely intra-ceramic defects, trauma, pressure from parafunction, contamination during manufacture, improper planning, endodontic factors, differences in thermal coefficient expansion of core and veneering ceramic, and inadequate tooth preparation.[10,11,12,13]

Ceramic fractures are often considered an emergency and become a challenge for dentists. Restoring crown and bridge restorations cannot be done in the patient's mouth, takes a long time, and requires more complex skills and tools. Removing a bridge or crown restoration is an unpleasant experience for the patient and tiring for the dentist. That is why replacing all restorations is not considered as the best solution because of the high costs and difficulties.[4,11,12] In order to repair broken ceramics with composite resins, the surfaces must be given surface treatment first, which includes mechanical and chemical treatment. Common mechanical treatments are grinding, abrasion with silica particles, aluminum oxide abrasion, acid etching, and a combination of these methords.[10,14]

The resin composite adheres well to dental ceramics when the substrate surface is mechanically prepared and a silane coupling agent applied.[11] The standard protocol for the treatment of vitreous ceramic is etching with hydrofluoric acid followed by application of silane coupling agent.[6,7,12,15,16,17] Hydrofluoric acid dissolves the glassy surface on the ceramic matrix so that the crystalline structure is exposed, and silane coupling agents act as hybrids of inorganic-organic compounds that create strong microscopic bonds between the two materials.[8,17,18] Although hydrofluoric acid is the suggested pretreatment for ceramic, this etchant is very toxic and may lead to accident in practice and also weakening the ceramic surface.[10,15,19]

The intraoral repairing ceramic technique's success with composite resin depends on the strong bond between the substrate and composite resin. Various ceramic repair systems on the market nowadays offer various techniques and steps. Since repairing ceramic with composite is chairside, clinician must choose the best technique and the most suitable ones in the market.

The purpose of this study was to compare the difference in shear bond strength between ceramic repair systems using grinding and universal primers with those using etching hydrofluoric acid and silane on lithium disilicate.

METHODS

The materials used in this study were two ceramic repair systems. Both ceramic repairs system claimed that the products could be used in ceramic. The first group was ceramic repair system from Ivoclar Vivadent. The manufacturer suggest to grind surfaces as mechanical treatment instead of using hydrofluoric acid. This system was including the universal primer (Monobond®), light-curing bonding agent (Heliobond), light cured opaquer (IPS Empress Direct Opaque) and light cured nano composite (Tetric® N Ceram). The second group was A.C.E ceramic repair kit from Preves, Denpro which included hydrofluoric acid etching (CeraEtch), Silane (Silane-X), light curing bonding agent (Renew Universal), and flowable composite (Fusion flo).

Ten ceramic blocks measuring 10 x 10 x 2mm were made using the hot-press technique (IPS EMax Press, Ivoclar Vivadent) according to the manufacturer's instructions. Each block mounted on an auto-polymerizing poly-methyl methacrylate resin that fits into the Universal Testing Machine's jig for a shear test. Blocks divided into two groups: 5 blocks will be treated with ceramic repair system one and another 5 blocks with ceramic repair system two.

Application of the ceramic repair system

In the first group, all blocks (10x10x2 mm) were treated with one protocol that follows the manufacturer's instructions. First, the surface ground with medium grit diamond burs (106-125 µm), then cleaned and air dried. Universal primer (Monobond®) was applied to the surface, left for 60 seconds, and dried. The surface was then treated by adhesive (Heliobond), dried for 2-5 seconds, and cured for 10 seconds. Composite resin (Tetric® N-Ceram) applied onto the surface and cured for 10 seconds.

The second group consisted of another 5 ceramic blocks that with procedures as follow: First, the surface etched with 5% hydrofluoric acid (Cera Etch) for 90 seconds, rinsed and air dried. Silane (Silane-X) was applied to the surface and dried for 60 seconds. Then the surface was treated with adhesive (Renew Universal) and cured for 20 seconds. Composite resin (Fusion Flo) was applied and cured for 40 seconds.

Shear bond strength test

Each block placed in a metal jig in a universal testing machine (Lloyd instruments). Loading parallel to the specimen's long axis was applied at the interface between composite resin and the ceramic surface under the load of 5.6 kN with 0,5 mm/minute crosshead speed until fracture. The maximum load at failure or delamination of the composite resin was recorded. Shear bond strengths (MPa) were calculated by dividing failure load (N) by bonding area (mm2).[13]

Statistical analysis

Shapiro-Wilk normality data analysis was performed to see normality distribution. Furthermore, Levene's test of equality of error variances was performed to assess the equality of variances in different groups. Then, the shear bond strengths within the group were analyzed by t-test parametric analysis *(one-tailed)*.

RESULTS

Data from all ten samples were recorded dan taken for statistical evaluation. Table 1 shows the mean and standard deviation value in each group. The highest mean shear strength was seen in Group 2 (13,51 MPa) compared to Group 1 (6.17 MPa). The shear bond strength of each group had normal distributions based on Shapiro-Wilk test (Table 2).

Table 1. Mean and standard deviation of shear bond strength

Samples	Mean (MPa)	SD
Group 1	6.17	2.65
Group 2	13.51	4.26

Table 2. Shapiro-Wilk normality data test of shear bond strength

Samples	Statistic	n	p value
Group 1	0.84	5	0.15
Group 2	0.90	5	0.41

Data was tested for the homogeneity using Lavene test with p value more than 0.05 thus indicating the data is homogenous. Homogeneity test results gained p value 0.19 and can be seen in Table 3.

Table 3. Levene homogeneity test result of shear bond strength

Samples	n	Mean	Variance	p value
Group 1	5	6.16	7.03	0.19
Group 2	5	13.51	18.17	

Then all the data was analysed using t test one tailed parametric statistic. Table 4 shows the result of t and p value of t-test. The p value < 0,05 indicates there is significant differences between shear bond strength in both groups. Independence group test gained t -3,27 and p-value (one tailed) 0,005. When the mean shear bond strength was compared within both groups, the second group (13,51 MPa) revealed statistically significant higher (p = 0.001) than the first group (6.17 MPa).

Table 4. The t-test (one tailed) results of shear bond strength

Samples	Mean	SD	Variance	t	p value
Group 1	6.17	2.65	12.60	-3,27	0.001
Group 2	13.51	4.26			

DISCUSSION

In this study, all samples in both groups was recorded and tested using SPSS® Statistics software. Table 1 shows the mean and standard deviation in both Groups. The result indicates that the shear strength value of lithium disilicate in ceramic repair system Group 2, which uses hydrofluoric acid etching and silane, is higher (13.51 MPa) than Group 1, which uses bur grinding and ceramic primers (6.17 MPa). The data in each group found to had normal distributions based on Shapiro-Wilk test as seen in Table 2. Furthermore, data was tested with Lavene test for homogeneity and show that the data was homogenous (Table 3). Then, all the data was analysed using t test one tailed parametric statistic. With p value less than 0,05, the mean shear strength in Group 2 was statistically significant higher than those in Group 1.

The success of composite resin as a substitute for the fractured ceramic surface is determined by the mechanical and chemical adhesion that precede it. The ceramic surface can be mechanically roughened with a diamond bur or by sandblasting with aluminium oxide, followed by hydrofluoric acid, and both can affect the bond strength.[4,10] This surface treatment aims to increase the surface roughness by forming micro or macro-porosities. Chemical adhesion involves modification of surface chemistry, where the two dissimilar surfaces are connected by a chemically active material, which is usually liquid and has bonding affinity to both surfaces.[13,16] This adhesion could be achieved with the help of coupling agent or primers. Silane coupling agent mainly related to hydroxylated (-OH) surfaces, in particular using methacryloxypropyltrimethoxysilane (MPS or y-MPS) to coupling reactions.[14,18] Adhesion occurs between the inorganic phase of the ceramic and the organic phase of the bonding agent applied to the ceramic surface, by forming a siloxane bond16 resulting in microscopic interactions between both parts.

As seen in Table 4, the result of this study indicates that the shear strength value of lithium disilicate in ceramic repair system Group 2, which uses hydrofluoric acid etching and silane, is higher (13.51 MPa) than Group 1, which uses bur grinding and ceramic primers (6.17 MPa). Grinding ceramic with burs is necessary to obtain micromechanical retention. This result also confirmed by several research reported roughening the surface with a diamond bur and sandblaster was quietly effective for porcelain repair.[10] Other authors stated that diamond bur roughening should be combined with other surface treatment methods in order to attain higher adhesion values.[4]

Hydrofluoric acid has been traditionally used as the etchant for porcelain and glass ceramic[7,8,16,17], but it is highly corrosive, may be absorbed into the blood and bone through the skin, and in higher concentration may lead to cardiac arrest.[15] It is suggested that the intraoral use of this acid should be minimized to reduce potential health hazards to patient and dental officers.[11] Other acids that are used as ceramic etchant are Acidulated Phosphate Fluoride (APF) and Ammonium Hydrogen Difluoride.[18]

Etching with acid has multiplied effect on ceramic: cleansing the bonding surface by removing the unwanted oxides, debris and grease, increasing the roughness thus increasing the bonding area and wettability of the ceramic surface and create micro retention that can be easily infiltrated with uncured flowable composite. This will significantly increase resin-ceramic bond strength.[18] The use of medium-grain diamond burs can produce roughness values comparable to those of hydrofluoric acid but it does not provide sufficient bond strength to be an alternative to acid etching.[6] This is because the acid etching creates more hydroxyl groups on the surface and increases micro-mechanical retention.[16] In an aqueous solution the alkoxy groups in silanes react with water to form reactive, hydrophilic, and acidic silanol groups for bonding to suitable inorganic surfaces. This silanol groups react with the surface of hydroxyl groups via chemical covalent bond Si-O-Si.[4,16,20] Additionally, there is an increase in surface energy and wettability after etching and silanization, which results in a decrease of the contact angle between the ceramics and resin composite.[21,22]

Blum et al.[11] studied the bond strength of four ceramic repair system in the market and found that system that used sandblasting and silane achieved highest value than other system. The other system were: group using phosphoric acid 37% and silane, grinding burs and silane, and last group that used phosphoric acid followed by universal primers. All ceramic repair system claimed that the systems offer high bond value to repair ceramic, but the effectiveness will depend on so many considerations.

Universal adhesives have been introduced by manufacturers to simplify the bonding procedure, provide the versality of a single-bottle product and reduce the procedure time. Phosphoric acid monomer solutions such as MDP (10-metacryloyloxydecyl dihydrogen phosphate) bonds non-glass ceramics with methacrylate groups through metal ion bonds. In order to achieve a simpler method, silane is also added to the “universal” adhesive material so that it can be used, both on enamel, dentin, ceramics (glass and non-glass), as well as metal alloys.[6,23]

Previous study by Elsayed et al.[24] compared universal primes and universal multimode adhesives to zirconia and lithium disilicate. Authors concluded that using a separate primer containing silane and phosphate monomer provides more durable bonding than do silanes incorporated in universal multimode adhesives, only one of five universal primers and adhesives provided durable bonding to lithium disilicate and zirconia ceramic.

Gomez et al.[23] also examined the use of ceramic primers over conventional silane in lithium disilicate. Samples were sandblasted with alumina particles and etched with 10% hydrofluoric acid and then grouped in groups: silane, self-etch ceramic primers, and universal adhesive. The result is conventional silane is more effective than universal adhesive and self-etch primers. Another conclusion is that the results of self-etch primers and universal adhesive were considered similar.

Studies by Lopes et al.[17] find a better result with the use of Hydrofluoric acid followed by a silane solution than a self-etching ceramic primers, which are functional monomer solutions with additional silane compared. Studied by de Siquera et al.[19] found similar bond strength between Hydrofluoric acid and self-etch ceramic primer, and combination of both treatments did not add any benefits. Similarly, no improvement in bond strength when silane was applied together with the self-etching primer.

Although the clinical use of a universal adhesives with silane in the same solution is very convenient to bond glass-matrix ceramics, the combination of silane and resin monomers in universal adhesives is controversial.[21] This may be because the extra resin monomer inhibited the condensation reaction between silanes and silica.4 Water contact angle measurements and bond strength testing have demonstrated that a silane may be incompatible with methacrylate monomers when mixed in the same solution.[21] The sense of having less silane quantity per area in contact with ceramic surface and thus reducing availability to link with the resin composites become another reason for this.[23] silane is an important step in the ceramic and composite bonding process and cannot be replaced, either by a self-etch ceramic primer (silane MDP) or universal adhesive.

Limitation of this study is that the test was not able to stimulate clinical loading forces and long-term aging under oral environment. The bond strength of a repair system is susceptible to chemical, thermal and mechanical influences under intraoral conditions. This results in a presumed weakening of bond strength of the repair system over time compared with this study. No predictions can be made in respect of the clinical longevity of repairs affected using the protocols tested in this study. As a consequence, the application of the repair systems tested may be limited for use as an interim measure only.

CONCLUSIONS

The bond strength of ceramic repairs on lithium disilicate using acid etching and silane is higher when compared to those using grinding and ceramic primers. Clinicians should take considerations about its protocol of safety and effectiveness.

REFERENCES

1. Tarib NA, Anuar N, Ahmad M. Shear bond strength of veneering ceramic to coping materials with different pre-surface treatments. J Adv Prosthodont. 2016; 8(5): 339-44. DOI: 10.4047/jap.2016.8.5.339
2. Anusavice KJ. Standardizing failures, success, and survival decisions in clinical studies of ceramic and metal ceramic fixed dental prostheses. Dent Mater. 2012; 28(1): 102-11. DOI: 10.1016/j.dental.2011.09.012
3. Gonzaga CC, Cesar PF, Miranda Jr WG, Yoshimura HN. Slow crack growth and reliability of dental ceramics. Dental Mater. 2011; 27(4): 394-406. DOI: 10.1016/j.dental.2010.10.025
4. Chen L, Suh BI. Bonding of resin materials to all-ceramics: A review. Curr Res Dent. 2012; 3(1): 7-17. DOI: 10.3844/crdsp.2012.7.17
5. Qamheya AHA, Qamheya M, Arisan V. Lithium disilicate restorations: Overview and a case report. J Dent Oral Disord. 2016 ;2(9): 1047.
6. Gonzales ACC, Mejia ED. Alternatives of surface treatments for adhesion of lithium disilicate ceramics. Rev Cuban Estomatol. 2018; 55(1): 59-72.
7. Yucel MT, Aykent F, Akman S, Yondem I. Effect of surface treatment methods on the shear bond strength between resin cement and all-ceramic core materials. J Non Crystal Solid. 2012; 358(5): 925-30. DOI: 10.1016/j.jnoncrysol.2012.01.006
8. Neto DS, Naves LZ, Costa AR, Correr AB, Consani S, Borges GA, et al. The effect of hydrofluoric acid concentration and application time on the bond strength and morphology of the surface and interface of glass ceramics to a resin cement. Oper Dent. 2015; 40(5): 470-9. DOI: 10.2341/14-133-L
9. Zhang Y, Sailer I, Lawn BR. Fatigue of dental ceramic. J Dent. 2013; 41(12): 1135-47. DOI: 10.1016/j.jdent.2013.10.007
10. Tolidis K, Gerasimou P, Boutsiouki C. Intraoral ceramic restoration repair techniques: Report of three cases. Balk J Storm 2012;16:103-8.
11. Blum IR, Nikolinakos N, Lynch CD, Wilson NHF, Millar BJ, Jagger DC. An in vitro comparison of four intra-oral ceramic repair systems. J Dent. 2012; 40(11): 906-12. DOI: 10.1016/j.jdent.2012.07.008
12. Yoo JY, Yoon HI, Park JM, Park EJ. Porcelain repair-influence of different systems and surface treatments on resin bond strength. J Adv Prosthodont. 2015; 7(5): 343-8. DOI: 10.4047/jap.2015.7.5.343
13. Özcan M, Volpato CAM. Intra-oral repair technique for ceramic fracture using direct resin composite. Italian J Dent Med. 2016; 1(2): 67-70.
14. Subaşı G, Inan O. Shear bond strength of three porcelain repair systems on porcelain in dry and aged conditions. Dentistry. 2012; 2: 119-26. DOI: 10.4172/2161-1122.1000119
15. Lyann SK, Takagaki T, Nikaido T, Uo M, Ikeda M, Sadr A, et al. Effect of different surface treatments on the tensile bond strength to lithium disilicate glass ceramic. J Adhes Dent. 2018; 20(3): 261-8. DOI: 10.3290/j.jad.a40632
16. Yavuz T, Eraslan O. The effect of silane applied to glass ceramics on surface structure and bonding strength at different temperatures. J Adv Prosthodont. 2016; 8(2): 75-84. DOI: 10.4047/jap.2016.8.2.75
17. Lopes GC, Perdigão J, Baptista D, Ballarin A. Does a self-etching ceramic primer improve bonding to lithium disilicate ceramics? Bond strengths and FESEM analyses. Oper Dent. 2019; 44(2): 210-8. DOI: 10.2341/17-355-L
18. Bajraktarova-Valjakova E, Grosdanov A, Guguvceski L, Korunuska-Stevkovska V, Kapusevska B, Gigovski N, et al. Acid etching as surface treatment method for luting of glass ceramic restorations, part 1: Acids, application protocol and etching effectiveness. Open Access Macedonian J Med Sci. 2018; 6(3):568-73. DOI: 10.3889/oamjms.2018.147
19. de Siquera FSF, Campos VS, Wendlinger M, Muso RAC, Gomes JC, Reis A, et al. Effect of self-etching primer associated to hydrofluoric acid or silane on bonding to lithium disilicate. Braz Dent J. 2019; 30(2): 171-8. DOI: 10.1590/0103-6440201902366
20. Moro AFV, Ramos AB, Rocha GM, Perez CDR. Effect of prior silane application of the bond strength of a universal adhesive to a lithium disilicate ceramic. J Prosthet

Dent. 2017; 118(5): 666-71. DOI: 10.1016/j.prosdent.2016.12.021
21. Cardenas AM, Siqueira F, Hass V, Malaquias P, Gutierrez MF, Reis A, et al. Effect of MDP-containing silane and adhesive used alone or in combination on the long-term bond strength and chemical interaction with lithium disilicate ceramics. J Adhes Dent. 2017; 19(3): 203-12. DOI: 10.3290/j.jad.a38414
22. Zakir M, Tian T, Ashraf U, Han A, Qiao W, Jin X, et al. The role of silane coupling agents and universal primers in durable adhesion to dental restorative materials – A review. Curr Oral Health Rep. 2016; 3(3): 244-53. DOI: 10.1007/s40496-016-0108-9
23. Gomez FM, De Goes MF. Effect of different silane-containing solutions on glass-ceramic/cement bonding interaction with dual cure resin cements. Int J Dent Sci. 2014; 16: 87-105.
24. Elsayed A, Younes F, Lehmann F, Kern M. Tensile bond strength of so-called universal primers and universal multimode adhesives to zirconia and lithium disilicate ceramics. J Adhes Dent. 2017; 19(3): 221-8. DOI: 10.3290/j.jad.a38436